APPENDIX O

HUMAN FACTORS ANALYSIS AND CLASSIFICATION SYSTEM (HFACS)

A. Introduction

Human error continues to plague both military and civilian aviation. Yet, simply writing off aviation mishaps to "pilot error" is a simplistic, if not naive, approach to mishap causation. Further, it is well established that mishaps are rarely attributed to a single cause, or in most instances, even a single individual. Rather, mishaps are the end result of a myriad of latent failures or conditions that precede active failures. The goal of a mishap investigation is to identify these failures and conditions in order to understand why the mishap occurred and how it might be prevented from happening again in the future.

As described by Reason (1990), active failures are the actions or inactions of operators that are believed to cause the mishap. Traditionally referred to as "pilot error", they are the last "unsafe acts" committed by aircrew, often with immediate and tragic consequences. For example, an aviator forgetting to lower the landing gear before touch down or flat-hatting through a box canyon will yield relatively immediate, and potentially grave, consequences.

In contrast, latent failures or conditions are errors that exist within the squadron or elsewhere in the supervisory chain of command that effect the tragic sequence of events characteristic of a mishap. For example, it is not difficult to understand how tasking crews at the expense of quality crew rest, can lead to fatigue and ultimately errors (active failures) in the cockpit. Viewed from this perspective then, the unsafe acts of aircrew are the end result of a chain of causes whose roots originate in other parts (often the upper echelons) of the organization. The problem is that these latent failures or conditions may lie dormant or undetected for hours, days, weeks, or longer until one day they bite the unsuspecting aircrew.

The question for mishap investigators and analysts alike, is how to identify and mitigate these active and latent failures or conditions. One approach is the "Domino Theory" which promotes the idea that, like dominoes stacked in sequence, mishaps are the end result of a series of errors made throughout the chain of command. A "modernized" version of the domino theory is Reason's "Swiss Cheese" model that

describes the levels at which active failures and latent failures/conditions may occur within complex flight operations (see Figure 1).

Working backward from the mishap, the first level of Reason's model depicts those *Unsafe Acts of Operators* (aircrew, maintainers, facility personnel, etc.) that ultimately lead to a mishap. Traditionally, this is where most mishap investigations have focused their examination of human error and consequently, where most causal factors are uncovered. After all, it is typically the actions or inactions of individuals that can be directly linked to the mishap. Still, to stop the investigation here only uncovers part of the story.

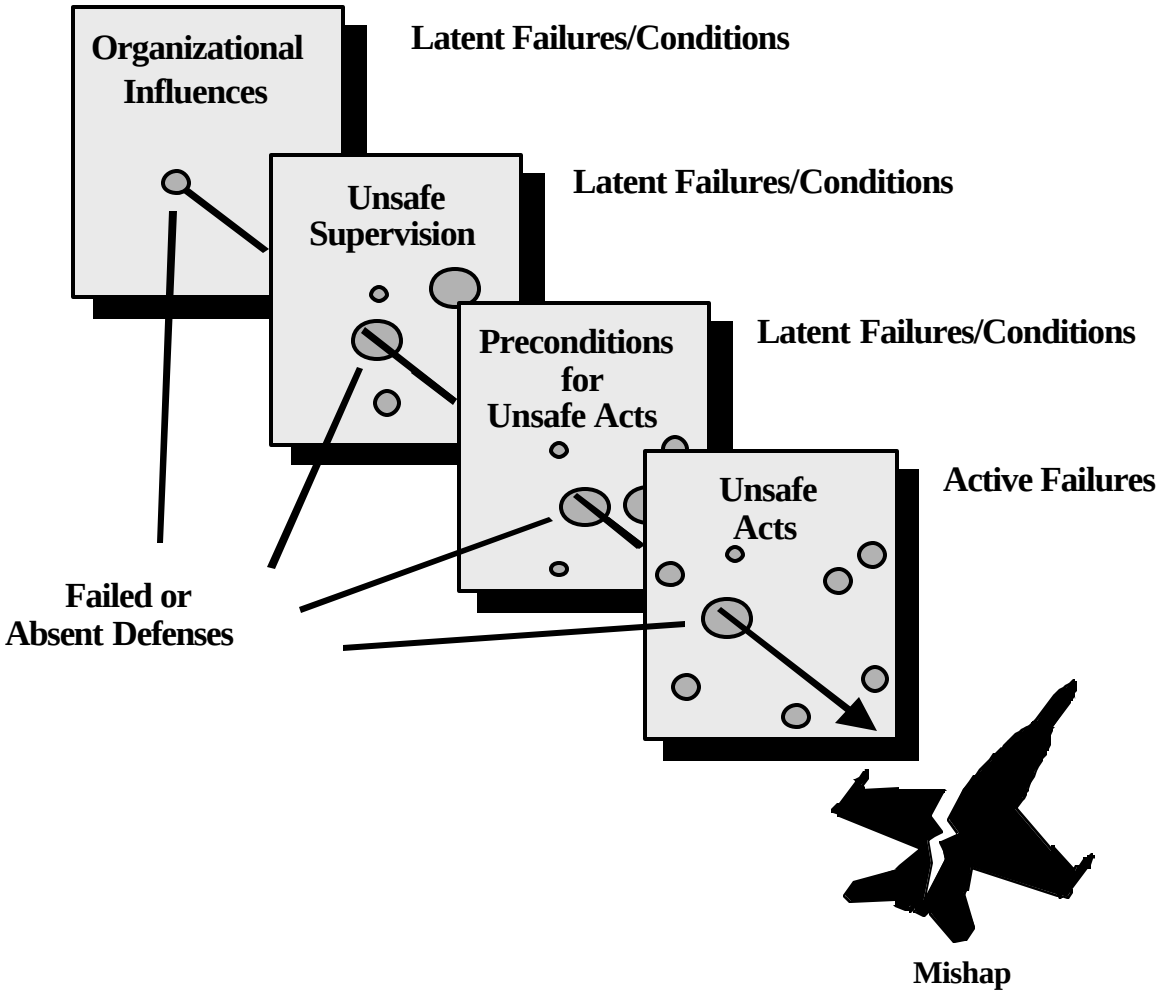

Figure 1. The "Swiss Cheese" Model (adapted from Reason, 1990).

What makes Reason's model particularly useful in mishap investigation, is that it forces investigators to address latent failures and conditions within the causal sequence of events. For instance, latent failures or conditions such as fatigue, complacency, illness, and the loss of situational awareness all effect performance but can be overlooked by investigators with even the best of intentions. These particular latent failures and conditions are described within the context of Reason's model as *Preconditions for Unsafe Acts*. Likewise, *Unsafe Supervision* can promote unsafe conditions of operators and ultimately unsafe acts will occur. For example, if an Operations Officer were to pair a below average Naval Aviator with a very junior Naval Flight Officer, the result is often predictable and sometimes tragic. Regardless, whenever a mishap does occur, the crew naturally bears a part of the responsibility and accountability. However, often the latent failures or conditions at the supervisory level were equally responsible for causing the mishap. In this particular example, the aircrew was set-up for failure.

Reason's model does not stop at supervision; it also considers *Organizational Influences* that can impact performance at all levels. For instance, in times of fiscal constraints, funding may be short, and consequently training flights limited. Supervisors are pressed to task "non-proficient" aviators with, at times, complex missions. Not surprisingly, episodes of task saturation and loss of situational awareness may appear and consequently performance in the cockpit will suffer. As such, causal factors at all levels must be addressed if any mishap investigation process is going to be effective.

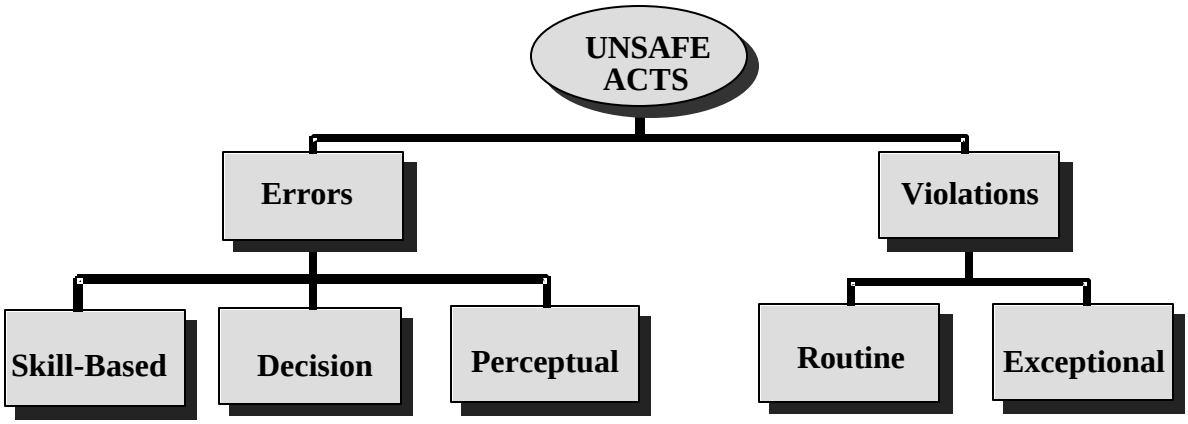

Figure 2. Categories of Unsafe Acts of Operators.

The investigation process then endeavors to detect and identify the "holes in the cheese" (see Figure 1). So how do we identify the holes in the Swiss Cheese? Aren't they really too numerous to define? After all, every mishap is unique, so the holes will always be different for each mishap ... right? Well, it turns out that each mishap is not unique from its predecessors. In fact, most mishaps have very similar causes. They are due to the same holes in the cheese, so to speak. Therefore, if you know what these system failures or "holes" are, you can better identify their roles in mishaps -- or better yet, detect their presence and correct them before a mishap occurs.

B. Human Factors Analysis and Classification System

Drawing upon Reason's (1990) concept of active failures and latent failures/conditions, a basic taxonomy was developed to identify the "holes" called the Human Factors Analysis and Classification System (HFACS). HFACS describes four levels of failures/conditions: 1) Unsafe Acts, 2) Preconditions for Unsafe Acts, 3) Unsafe Supervision, and 4) Organizational Influences. A brief description of the major components and causal categories follows, beginning with the level most closely tied to the mishap, unsafe acts.

1. Unsafe Acts

The Unsafe Acts committed by aircrew generally take on two forms, *Errors and Violations* (see Figure 2). The first, Errors, are not surprising given the fact that human beings by their very nature make errors. Consequently, aircrew errors are seen in most mishaps, often as the final event before a mishap occurs. Violations, on the other hand, are less frequent and represent a willful disregard for the rules. Not all Unsafe Acts (both Errors and Violations) are alike. Consequently the Unsafe Acts aircrew commit can be classified among three basic types of Errors (Skill-based, Decision, & Perceptual) and two forms of Violations (Routine & Exceptional). Using this simple classification scheme, the investigator must first determine if an operator committed an Unsafe Act (active failure). If so, the investigator must then decide if an error occurred or a rule was willfully violated. Once this is done, the investigator can further define the causal factor as a specific type of Error or Violation.

a. Basic Error Forms

(1) Skill-based Errors. Skill-based behavior is best described as those "stick-and-rudder" or other basic flight skills that occur without significant conscious thought. As a result, skill-based actions are particularly vulnerable to failures of attention and/or memory. In fact, attention failures have been linked to many Skill-based Errors such as the breakdown in visual scan patterns, task fixation, inadvertent control activation, and misordering procedural steps, among others. For example, consider a pilot so intent on putting bombs on target that he disregards his low altitude warning only to collide with the ground. Putting a switch into the wrong mode or missing a runway change because of a distraction are examples of attention failures that occur during highly automatized behavior.

In contrast to attention failures, memory failures often appear as omitted checklist items, losing place, or forgotten intentions. For example, it is not difficult to imagine that in emergency situations under stress, steps in boldface emergency procedures or radio calls could be missed. Even when not particularly stressed, individuals forget to set the flaps on approach or lower the landing gear.

Skill-based Errors can happen even when no apparent attention of memory failure is present. The individual flying skill/techniques of Naval Aviators differ from one pilot to next and can range from individuals that fly effortlessly to those who don't fly so effortlessly. It is the Skill-based Errors of the latter that often leads to a mishap. The bottom line is that Skill-based Errors are unintended behaviors. That is, individuals typically do not choose to limit their scan patterns, forget a boldface procedure, or fly poorly -- it just happens (see Table 1).

(2) Decision Errors. Intentional behaviors that prove to be inappropriate or inadequate for the situation are Decision Errors. Often referred to as "honest mistakes", these Unsafe Acts represent the actions or inactions of individuals whose intentions were good, but they either did not have the appropriate knowledge or just simply chose poorly.

Decision Errors come in many forms, and occur for a variety of reasons, but they typically represent poor decision-making, improper procedural execution, or the misuse

Table 1. Select Examples of Unsafe Acts of Operators	
ERRORS	VIOLATIONS
<u>Skill-based Errors</u> Breakdown in Visual Scan Delayed Response Failed to Prioritize Attention Failed to Recognize Extremis Improper Instrument Cross-Check Inadvertent use of Flight Controls Omitted Step in Procedure Omitted Checklist Item	<u>Routine</u> Failed to Adhere to Brief Violation of NATOPS/Regulations/SOP - Failed to use RADALT - Flew an unauthorized approach - Failed to execute appropriate rendezvous - Violated training rules - Failed to adhere to departure procedures - Flew overaggressive maneuver - Failed to properly prepare for flight
<u>Decision Errors</u> Improper Takeoff Improper Approach/Landing Improper Procedure Wrong Response to Emergency Exceeded Ability Inappropriate Maneuver	<u>Exceptional</u> Briefed Unauthorized Flight Not Current/Qualified for Mission Intentionally Exceeded the Limits of the Aircraft Violation of NATOPS/Regulations/SOP - Continued low-altitude flight in VMC - Failed to ensure compliance with rules - Unauthorized low-altitude canyon running - Not current for mission - Flathatting on takeoff - Briefed and flew an unauthorized maneuver
<u>Perceptual Errors</u> Misjudged Distance/Altitude/Airspeed Spatial Disorientation Visual Illusion	

or misinterpretation of relevant information. The bottom line is that the individual made a conscious choice and elected to do what was done in the cockpit -- unfortunately, in the case of a mishap, it did not work (see Table 1).

(3) <u>Perceptual Errors</u>. Not surprisingly, when your perception of the world is different than reality, errors can, and often do, occur. Typically, Perceptual Errors occur when sensory inputs are degraded or 'unusual,' as is the case when visual illusions or spatial disorientation occur. Visual illusions can occur when the brain tries to 'fill in the gaps' in a visually impoverished environment, like that seen at night or in degraded weather. Likewise, spatial disorientation can occur when the vestibular system cannot properly resolve orientation in space and therefore makes a "best guess" -- typically when visual horizon cues are absent at night or in poor weather. In either event, the individual is left to act on faulty information leading to error, and often a mishap. Likewise, it is often quite difficult to judge precise distance and closure between aircraft and the ground when relative cues like clouds or terrain features are

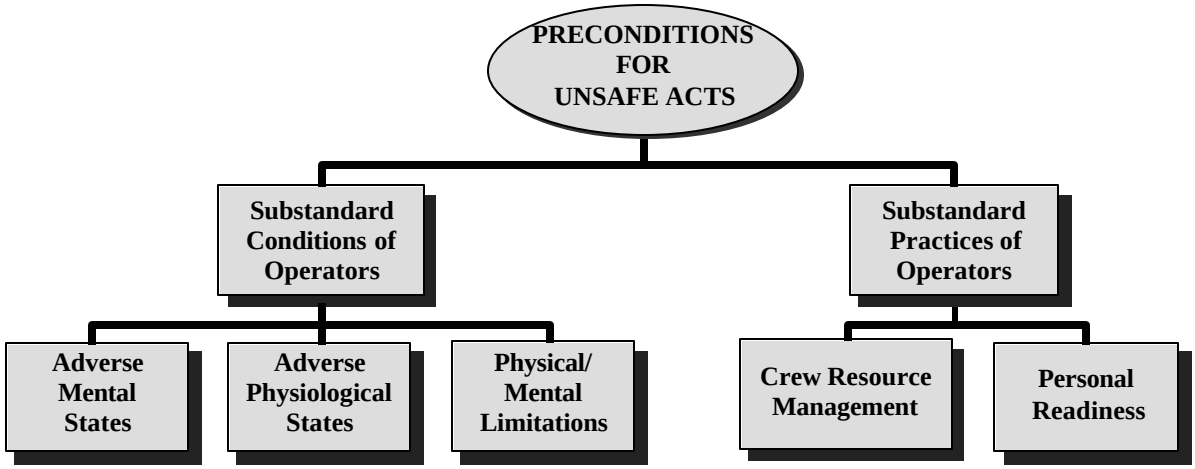

Figure 3. Categories of Preconditions for Unsafe Acts

absent. Consequently, aircrew are left to make control inputs based on misperceived or absent information. Tragically, such errors often lead to midair collisions or controlled flight into terrain (see Table 1).

b. Violations

(1) Routine. In general, Violations are the willful departure from authority that simply cannot be tolerated. Infractions tend to be routine/habitual by nature, constituting a part of the individual's behavioral repertoire. For example, consider an aviator that does not wear flight gloves or an oxygen mask on take-off. While certainly against the NATOPS, many aviators continue not to comply. Consequently, these individuals 'routinely' violate this requirement. Commonly referred to as rule "bending", these Routine Violations are in effect tolerated by supervisory authority. If however, the chain of command started enforcing the rules, it is less likely that individuals would develop/maintain the habit of bending them. Therefore, by definition, if a Routine Violation is uncovered, one must look at the supervisory chain to identify the individuals that are condoning the violations (see Table 1).

(2) Exceptional. Unlike Routine Violations, Exceptional Violations appear as isolated departures from authority, not necessarily indicative of an individual's typical behavior pattern or condoned by management. For example, an impromptu air show or 'flathatting' is considered an Exceptional Violation. It is important to note that while most Exceptional Violations are heinous, they are not considered 'exceptional' because of their extreme nature but

Table 2. Select Examples of Preconditions for Unsafe Acts	
SUBSTANDARD CONDITIONS	SUBSTANDARD PRACTICES
Adverse Mental States	Crew Resource Management
Channelized Attention	Failed to Back-up
Complacency	Failed to Communicate/Coordinate
Distraction	Failed to Conduct Adequate Brief
Life Stress	Failed to Use All Available Resources
Loss of Situational Awareness	Failure of Leadership
Mental Fatigue	Misinterpretation of Traffic Calls
Task Fixation	Trans-cockpit Authority Gradient
Haste to Get Home	
Misplaced Motivation	
Adverse Physiological States	Personal Readiness
G-Induced Loss of Consciousness	Excessive Physical Training
Physiological Incapacitation	Self-Medicating
Physical Fatigue	Violation of Crew Rest Requirement
Spatial Disorientation	Violation of Bottle-to-Brief Rule
Visual Illusions	
Medical Illness	
Physical/Mental Limitation	
Insufficient Reaction Time	
Visual Limitation	
Incompatible Physical Capability	
Incompatible Intelligence/Aptitude	

rather because they are neither typical of the individual nor condoned by authority (see Table 1).

2. Preconditions for Unsafe Acts

Arguably, the Unsafe Acts of operators can be directly linked to the majority of Naval Aviation mishaps. However, simply focusing on Unsafe Acts is like focusing on a symptom without understanding the underlying cause(s). As such, investigators must dig deeper into why an unsafe act took place. As a first step, there are two major forms of Preconditions for Unsafe Acts, each with their specific causal categories (see Figure 3). Specifically, they include the *Substandard Conditions of Operators* (Adverse Mental States, Adverse Physiological States, & Physical/Mental Limitations) as well as the *Substandard Practices of Operators* (Crew Resource Management & Personal Readiness).

a. Substandard Conditions of Operators

(1) Adverse Mental States. Being prepared mentally is critical in nearly every endeavor, perhaps more so in aviation. As such, the category of Adverse Mental States takes into account those mental conditions that affect performance. Principle among these is the loss of situational awareness, task fixation, distraction, and mental fatigue due to sleep loss or other stressors. Also included in this category are personality traits and attitudes such as overconfidence, complacency, and misplaced motivation. For example, if an individual is mentally tired, for whatever reason, the likelihood that an error will occur increases. Likewise, overconfidence, complacency, etc. will influence the likelihood that a violation will be committed (see Table 2).

(2) Adverse Physiological States. Medical or physiological conditions that preclude safe operations are referred to as Adverse Physiological States. Particularly important to Naval Aviation are conditions such as spatial disorientation, visual illusions, G-induced loss of consciousness (G-LOC), hypoxia, physical fatigue, and the myriad of pharmacological and medical abnormalities known to affect performance. If, for example, an individual were suffering from a middle-ear infection, the likelihood of spatial disorientation occurring when entering instrument conditions goes up markedly. Consequently, the medical condition must be addressed within the causal chain of events (see Table 2).

(3) Physical/Mental Limitations. Instances when the mission requirements exceed the capabilities of the individual at the controls are denoted as Physical/Mental Limitations. They can take many forms. At night, for example, our visual system is limited by the capability of the sensors in our eyes and hence vision is severely degraded. Yet, operators do not necessarily slow down or take additional precautions. In aviation, this often results in not seeing other aircraft, obstacles, or power lines due to the size or contrast of the object in the visual field. Similarly, there are occasions when the task completion time or maneuver exceeds human capacity. It is well documented that if individuals are required to respond quickly the probability of making an error goes up markedly.

There are two other instances of Physical/Mental Limitations that are often overlooked in most mishap

investigations and involve individuals who simply are not compatible with aviation. For example, some individuals do not have the physical strength to operate in high-G environments or for anthropometric reasons simply have difficulty reaching the controls. In other words, cockpits have not traditionally been designed with all shapes, sizes, and physical abilities in mind. Likewise, not everyone has the mental ability or aptitude for flying aircraft. The challenge is identifying whether physical or mental limitations played a role in a mishap event (see Table 2).

b. Substandard Practices of Operators

(1) Crew Resource Management. Occurrences of poor coordination among aircrew and other personnel associated with the safe conduct of the flight falls under Crew Resource Management (CRM). This includes coordination within and between aircraft, ATC, and maintenance control, as well as facility and other support personnel. Anywhere communication between individuals is required, the potential for miscommunication, or simply poor resource management, exists. However, CRM does not stop with the aircrew in flight. It also includes communicating before and after the flight (i.e., pre-flight brief, post-flight debrief). The conscientious investigator must always look for potential poor CRM practices (see Table 2).

(2) Personal Readiness. In aviation, or for that matter in any occupational setting, individuals are expected to show up for work ready to perform at optimal levels. For Naval Aviation, however, Personal Readiness Failures (see Table 2) occur when individuals fail to properly prepare physically or mentally for flight. For instance, violations of crew rest requirements, bottle-to-brief rules, and self-medicating all will affect performance in the aircraft. It is not hard to imagine that when an aircrew member violates crew

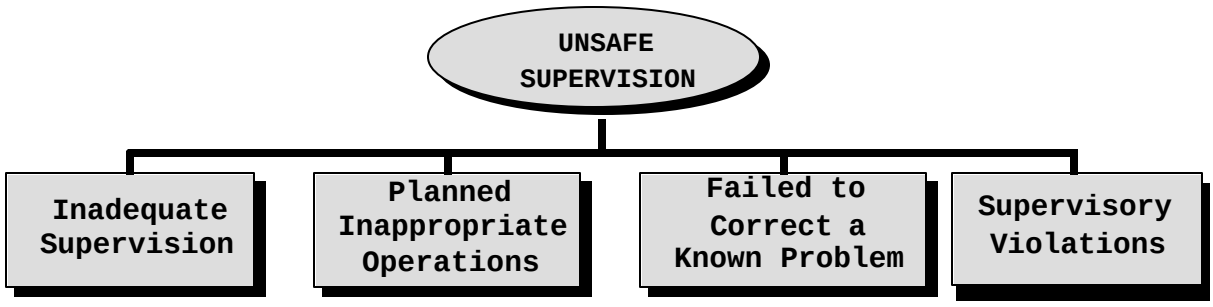

Figure 4. Categories of Unsafe Supervision

rest requirements, that individual runs the risk of mental fatigue and other adverse mental states. (*Note that violations that effect personal readiness are not considered "unsafe acts, violation" since they typically do not happen in the cockpit, nor are they active failures with direct and immediate consequences*)

Still, not all Personal Readiness failures occur as a result of violations of rules. For example, running 10 miles before a flight may not be against any existing regulations, yet it may impair an individual's physical and mental capabilities so as to degrade performance and elicit Unsafe Acts. Also, an aviator's traditional "candy bar and Coke" lunch may sound good, but may not be sufficient to sustain performance. Even cramming for a NATOPS exam may significantly impair sleep and consequently performance the next day in the cockpit. While there may be no rules governing such behaviors, aircrew must be their own best judge and objectively assess their Personal Readiness before manning an aircraft.

3. Unsafe Supervision

The Naval Safety Center has determined that a mishap event can often be traced back to the supervisory chain of command. As such, there are four major categories of Unsafe Supervision: *Inadequate Supervision*, *Planned Inappropriate Operations*, *Failed to Correct a Known Problem*, and *Supervisory Violations* (see Figure 4).

a. Inadequate Supervision. The role of supervisors are to provide their troops with the opportunity to succeed. To

Table 3. Select Examples of Unsafe Supervision

Inadequate Supervision	Failed to Correct a Known Problem
Failed to Provide Guidance	Failed to Correct/Document an Error
Failed to Provide Oversight	Failed to Identify an At-Risk Aviator
Failed to Provide Training	Failed to Initiate Corrective Action
Failed to Track Qualifications	Failed to Report Unsafe Tendencies
Failed to Track Performance	
	Supervisory Violations
Planned Inappropriate Operations	Authorized Unnecessary Hazard
Failed to Provide Correct Data	Failed to Enforce NATOPS/Regs/SOP
Improper Manning	Failed to Enforce T&R Manual
Mission Not IAW with NATOPS/Regs/SOP	Authorized Unqualified Crew for Flight
Permitted Unnecessary Hazard	
Provided Inadequate Opportunity for Crew Rest	

do this, supervisors, no matter what level they operate at, must provide guidance, training opportunities, leadership, motivation, and the proper role model. Unfortunately, this is not always the case. It is not difficult to imagine a situation where adequate CRM training was not provided to an aircrew member. Conceivably, the aircrew's coordination skills would be compromised, and if put into an adverse situation (e.g., emergency), they would be at risk for errors and potentially a mishap. Therefore, the category Inadequate Supervision accounts for those times when supervision proves inappropriate, improper, or may not occur at all (see Table(3).

b. Planned Inappropriate Operations. Occasionally, the operational tempo or schedule is planned such that individuals are put at unacceptable risk, crew rest is jeopardized, and ultimately performance is adversely affected. Such Planned Inappropriate Operations, though arguably unavoidable during emergency situations, are not acceptable during normal operations. Included in this category are issues of crew pairing and improper manning. For example, it is not surprising to anyone that when two individuals with marginal skills are paired together, problems can arise. During a period of downsizing and/or increased levels of operational commitment, it is often more difficult to manage crews. However, pairing weak or inexperienced aircrew together on the most difficult missions may not be prudent (see Table 3).

Figure 5. Categories of Organizational Influences

c. Failed to Correct a Known Problem. Failed to Correct a Known Problem, refers to those instances when deficiencies among individuals, equipment, training or other related safety areas are "known" to the supervisor, yet are allowed to continue uncorrected. For example, the failure to consistently correct

or discipline inappropriate behavior certainly fosters an unsafe atmosphere, and poor command climate (see Table 3).

d. Supervisory Violations. Supervisory Violations, on the other hand, are reserved for those instances when existing rules and regulations are willfully disregarded by supervisors. For instance, permitting an individual to operate an aircraft without current qualifications is a flagrant violation that invariably sets the stage for the tragic sequence of events that predictably follow (see Table 3).

4. Organizational Influences

Fallible decisions of upper-level management directly effect supervisory practices, as well as the conditions and actions of operators. These latent conditions generally involve issues related to *Resource Management, Organizational Climate, and Operational Processes* (see Figure 5).

a. Resource Management. This category refers to the management, allocation, and maintenance of organizational resources--human, monetary, and equipment/facilities. The term 'human' refers to the management of operators, staff, and maintenance personnel. Issues that directly influence safety include selection (including background checks), training, and staffing/manning. 'Monetary' issues refer to the management of nonhuman resources, primarily monetary resources. For example, excessive cost cutting and lack of funding for proper equipment have adverse effects on operator performance and safety. Finally, 'equipment/facilities' refers to issues

Table 4. Select Examples of Organizational Influences

RESOURCE/ACQUISITION	ORGANIZATIONAL CLIMATE	ORGANIZATIONAL PROCESSES
Human Resources	Structure	Operations
Selection	Chain-of-Command	Operational Tempo
Staffing/Manning	Delegation of Authority	Time Pressure
Training	Communication Channels	Production Quotas
	Formal Accountability	Incentives
Monetary/Budget Resources		Measurement/Appraisal
Excessive Cost Cutting	Policies	Schedules
Lack of Funding	Hiring and Firing	Deficient Planning
	Promotion	
Equipment/Facility		Procedures
Resources	Culture	Standards
Poor Design	Norms and Rules	Documentation
Purchasing of Unsuitable	Values and Beliefs	Instructions
Equipment	Organizational Justice	
		Oversight
		Risk Management
		Safety Programs

related to equipment design, including the purchasing of unsuitable equipment, inadequate design of work spaces, and failures to correct known design flaws. Management should ensure that human-factors engineering principles are known and utilized and that specifications for equipment and workspace design are identified and met (see Table 4).

b. Organizational Climate. Organizational Climate refers to a broad class of organizational variables that influence worker performance. It can be defined as the situational consistencies in the organization's treatment of individuals. In general, Organizational Climate is the prevailing atmosphere or environment within the organization. Within the present classification system, climate is broken down into three categories--structure, policies, and culture. The term 'structure' refers to the formal component of the organization. The 'form and shape' of an organization are reflected in the chain-of-command, delegation of authority and responsibility, communication channels, and formal accountability for actions. Organizations with maladaptive structures (i.e., do not optimally match to their operational environment or are unwilling to change) will be more prone to mishaps. 'Policies' refer to a course or method of action that guides present and future decisions. Policies may refer to hiring and firing, promotion, retention, raises, sick leave, drugs and alcohol, overtime, accident investigations, use of safety equipment, etc. When these policies are ill defined, adversarial, or conflicting, safety may be reduced. Finally, 'culture' refers to unspoken or unofficial rules, values, attitudes, beliefs, and customs of an organization ("The way things really get done around here."). Other issues related to culture include organizational justice, psychological contracts, organizational citizenship behavior, esprit de corps, and union/management relations. All these issues affect attitudes about safety and the value of a safe working environment (see Table 4).

c. Organizational Processes. This category refers to the formal process by which 'things get done' in the organization. It is subdivided into three broad categories--operations, procedures, and oversight. The term 'operations' refers to the characteristics or conditions of work that have been established by management. These characteristics included operational tempo, time pressures, production quotas, incentive systems, schedules, etc. When set up inappropriately, these working conditions can be detrimental to safety. 'Procedures' are the official or formal procedures

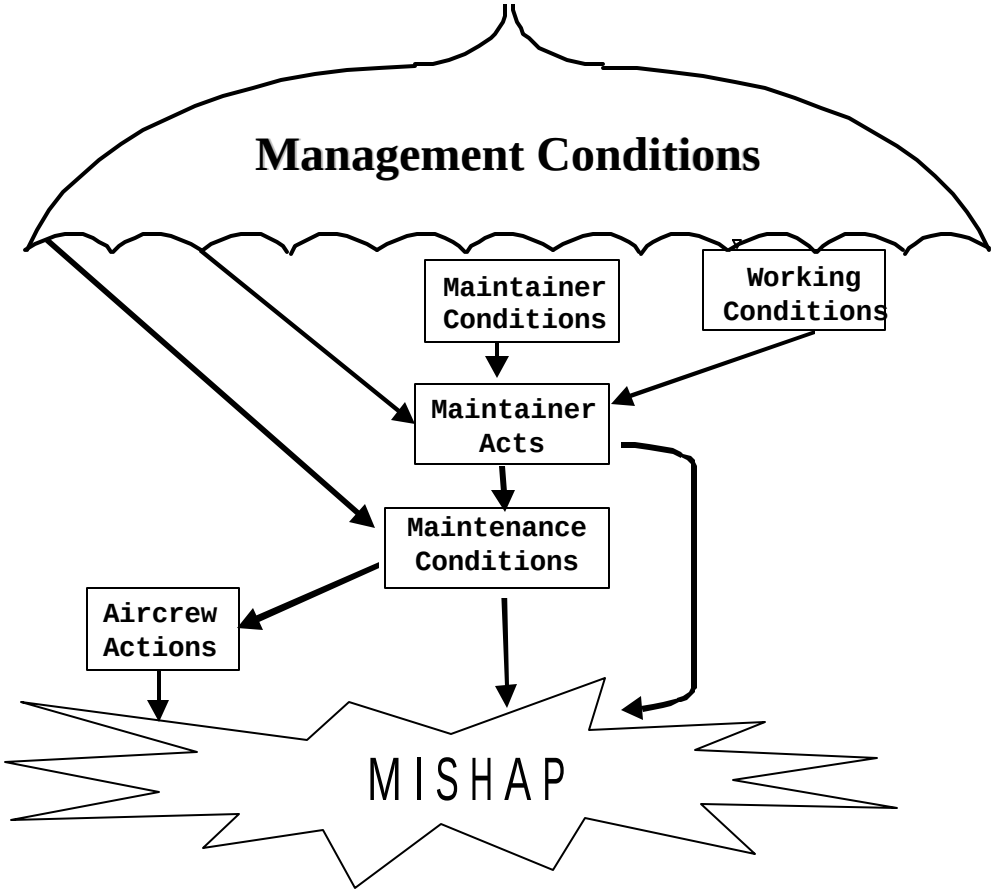

Figure 6. The HFACS - Maintenance - Extension (HFACS-ME)

as to how the job is to be done. Examples include performance standards, objectives, documentation, instructions about procedures, etc. All of these, if inadequate, can negatively impact employee supervision, performance, and safety. Finally, 'oversight' refers to monitoring and checking of resources, climate, and processes to ensure a safe and productive work environment. Issues here relate to organizational self-study, risk management, and the establishment and use of safety programs (see Table 4).

C. HFACS -- MAINTENANCE EXTENSION

HFACS has been adapted to capture maintenance human factors. Termed the "Maintenance Extension" (HFACS-ME), it facilitates the recognition of absent or defective defenses at four levels, including, Unsafe: *Management Conditions* (Organizational & Supervisory), *Maintainer Conditions, Working Conditions*, and *Maintainer Acts* (see Figure 6). This framework can be used to identify targets for intervention. HFACS-ME clearly addresses Marx's (1998) valid concern that

Table 5. HFACS-ME Taxonomy		
First Order	**Second Order**	**Third Order**
Management Conditions	Organizational	Inadequate Processes Inadequate Documentation Inadequate Design Inadequate Resources
	Supervisory	Inadequate Supervision Inappropriate Operations Uncorrected Problem Supervisory Misconduct
Maintainer Conditions	Medical	Adverse Mental State Adverse Physical State Unsafe Limitation
	Crew Coordination	Inadequate Communication Inadequate Assertiveness Inadequate Adaptability/Flexibility
	Readiness	Inadequate Training/Preparation Inadequate Certification/Qualification Personnel Readiness Infringement
Working Conditions	Environment	Inadequate Lighting/Light Unsafe Weather/Exposure Unsafe Environmental Hazards
	Equipment	Damaged/Unserviced Unavailable/Inappropriate Dated/Uncertified
	Workspace	Confining Obstructed Inaccessible
Maintainer Acts	Error	Attention/Memory Knowledge/Rule Skill/Technique Judgment/Decision
	Violation	Routine Infraction Exceptional Flagrant

human error has been "under-served" by traditional maintenance error analysis systems.

Unsafe Management, Maintainer, and Working Conditions are latent conditions that can impact a maintainer's performance and lead to an Unsafe Maintainer Act, an active failure. An Unsafe Maintainer Act may directly cause a mishap or injury (e.g., a maintainer runs a forklift into the side of an aircraft and damages it). It could also cause an Unsafe Maintenance Condition, which the aircrew would have to deal with on take-off, in-flight, or on landing (e.g., an over-

Table 6. Select Examples of Unsafe Management Conditions	
ORGANIZATIONAL	SUPERVISORY
Inadequate Processes	Inadequate Supervision
Task Complex/Confusing	Task Planning/Organization
Procedures Incomplete	Task Delegation/Assignment
Non-Existing Procedures	Amount of Supervision
Inadequate Documentation	Inappropriate Operations
Not Understandable	Information Not Used
Information Unavailable	Unrealistic Expectations
Conflicting Information	Improper Task Prioritization
Inadequate Design	Uncorrected Problem
Poor Layout/Configuration	Manual Not Updated
Poor/No Accessibility	Parts/Tool Incorrectly Labeled
Easy to Incorrectly Install	Known Hazards Not Controlled
Inadequate Resources	Supervisory Misconduct
Parts Unavailable	Policy/Procedures Not Followed
Manning Shortfall	Policy/Procedures Not Enforced
Funding Constraint	Assigned Unqualified Maintainer

torqued hydraulics line that fails in flight causing a fire or an improperly rigged landing gear that collapses on touchdown). Finally, it is important to note that Unsafe Management Conditions related to design for maintainability, prescribed maintenance procedures, and/or standard maintenance operations can be inadequate and lead to Unsafe Maintenance Conditions. Each major component of HFACS-ME has three orders that reflect a shift from a macro to a micro perspective (see Table 5).

For the most part HFACS-ME is used much the same way for maintenance factors as HFACS is for aircrew factors. For example, a supervisor who fails to correct a maintainer who routinely bends the rules while performing maintenance would be considered an Unsafe Management Supervisory Condition, failure to correct a known problem. Similarly, a maintainer who has a marital problem and cannot focus on a maintenance operation has fallen prey to an Unsafe Maintainer Medical Condition (Adverse Mental State). Further, a maintainer who must work in a heavy rain could experience difficulty due to an Unsafe Working Environmental Condition (Unsafe Weather/Exposure). Ultimately these conditions could lead to Unsafe Maintenance Acts such as reversing a step in a procedure (Attention/Memory Error) as well as not using the prescribed manual (Routine Violation). The following

Table 7. Select Examples of Unsafe Maintainer Conditions		
MEDICAL	CREW COORDINATION	READINESS
Adverse Mental State	Inadequate Communication	Inadequate Training/Preparation
Peer Pressure	Non Standard Hand Signals	New/Changed Task
Complacency	Inappropriate Log Entry	Inadequate Skills
Life Stress	Inadequate Shift Passdown	Inadequate Knowledge
Adverse Physical State	Inadequate Assertiveness	Inadequate Certification/Qualification
Health/Illness	Peer Pressure	Not Certified for Task
Fatigue	Rank Gradient	Incomplete PQS
Circadian Rhythm	New to Group	Not Licensed to Operate
Unsafe Limitation	Inadequate Adaptability/Flexibility	Personnel Readiness Infringement
Body Size/Strength	Non-adherence to Change	Self-Medication
Eye Sight/Hearing	Different from Similar Tasks	Alcohol Use
Reach/View	Disregard of Constraint	Crew Rest

paragraphs provide a brief illustration of the four major components of the HFACS-ME taxonomy.

Unsafe Management Conditions

Management Conditions that contribute to active failures consists of both Organizational and Supervisory factors (see Table 6). Examples of Organizational Management Conditions are: a manual omits a step calling for an o-ring to be installed (Inadequate Processes); a technical publication does not specify torque requirements (Inadequate Documentation); a poor component layout prohibits direct viewing during inspection (Inadequate Design); and a shortage of tools leads to using what is immediately available (Inadequate Resources). Examples of Supervisory Management Conditions include: a commander does not ensure that personnel wear required protective gear (Inadequate Supervision); an engine change is performed despite a high sea state without considering the risks (Inappropriate Operations);

Table 8. Select Examples of Unsafe Working Conditions		
ENVRIONMENT	EQUIPMENT	WORKSPACE
Inadequate Lighting/Light	Damaged/Unserviced	Confining
Inadequate Natural Light	Unsafe/Hazardous	Constrained Tool Use
Inadequate Artificial Lighting	Unreliable/Faulty	Constrained Equipment Use
Dusk/Nighttime	Inoperable/Uncontrollable	Constrained Position
Unsafe Weather/Exposure	Unavailable/Inappropriate	Obstructed
Temperature	Unavailable for Use	Not Visible
Precipitation	Inappropriate for Task	Not Directly Visible
Wind	Power Sources Inadequate	Partially Visible
Unsafe Environmental Hazards	Dated/Uncertified	Inaccessible
High Noise Levels	Unreliable/Faulty	Totally Inaccessible
Housekeeping/Cleanliness	Inoperable/Uncontrollable	Not Directly Accessible
Hazardous/Toxic Substances	Miscalibrated	Partially Accessible

a supervisor does not correct cutting corners in a procedure (Uncorrected Problem); and a supervisor orders personnel to wash an aircraft without training (Supervisory Misconduct).

Unsafe Maintainer Conditions

Maintainer Conditions that lead to active failures consists of Medical, Crew Coordination, and Readiness factors (see Table 7). Examples of Maintainer Medical Conditions are: a maintainer with life stress has impaired concentration (Adverse Mental State); a maintainer is fatigued from working 20 hours straight (Adverse Physical State); and a short maintainer cannot visually inspect an aircraft component (Unsafe Limitation). Examples of Maintainer Crew Coordination conditions include: a maintainer using improper hand signals (Inadequate Communication); a maintainer signs off an inspection due to perceived pressure (Inadequate Assertiveness); a maintainer downplays a discrepancy to meet the flight schedule (Inadequate Adaptability/ Flexibility). Examples of Maintainer Readiness Conditions

Table 9. Select Examples of Unsafe Maintainer Acts

ERROR	VIOLATION
Attention/Memory	Routine(if norm)/Infraction (if isolated)
Omitted Procedural Step	Inappropriate Tools/Equipment
Distraction/Interruption	Procedures Skipped/Reordered
Failed to Recognize Condition	Did Not Use Publication
Knowledge/Rule Based	Exceptional (if minor)/Flagrant(if blatant)
Inadequate Task Knowledge	Gundecking Qualifications
Inadequate Process Knowledge	Not Using Required Equipment
Inadequate Aircraft Knowledge	Signed-off Without Inspection
Skill/Technique Based	
Poor Technique	
Inadequate Skills	
Inappropriate Technique	
Judgment/Decision-Making	
Exceeded Ability	
Misjudged/Misperceived	
Misdiagnosed Situation	

encompass: a maintainer working on an aircraft skipped a requisite training evolution (Inadequate Training/Preparation); a maintainer engages in a procedure they have not been qualified to perform (Inadequate

Certification/Qualification), and a maintainer is intoxicated on the job (Personnel Readiness Infringement).

Unsafe Working Conditions

Working Conditions that can precipitate active failures consists of Environment, Equipment, and Workspace factors (see Table 8). Examples of Environment Working Conditions are: a maintainer working at night without artificial lighting (Inadequate Lighting/Light); a maintainer securing an aircraft in a driving rain improperly chocks a wheel (Unsafe Weather/Exposure); and a maintainer slips on a pitching deck (Unsafe Environmental Hazard). Examples of Equipment Working Conditions include: a maintainer uses a faulty test set (Damaged/Unserviced); a maintainer does not use a jack because all are in use (Unavailable/Inappropriate); a maintainer uses an out of date manual (Dated/Uncertified). Examples of Workspace Working Conditions encompass: a maintainer in a fuel cell cannot reach a component (Confining); a maintainer's view in spotting an aircraft is obscured by catapult steam (Obstructed); and a maintainer is unable to perform a corrosion inspection that is beyond his reach (Inaccessible).

Unsafe Maintainer Acts

Maintainer Acts are active failures which directly or indirectly cause mishaps, or lead to a Latent Maintenance Condition that an aircrew would have to respond to during a given phase of flight. Unsafe Maintainer Acts include Errors and Violations (see Table 9). Examples of Errors in Maintainer Acts include: a maintainer misses a hand signal (Attention/Memory); a maintainer inflates a tire using a pressure required by a different aircraft (Knowledge/Rule); a maintainer roughly handles a delicate engine valve causing damage (Skill/Technique); and a maintainer misjudges the distance between a tow tractor and an aircraft wing (Judgment/Decision-Making). Examples of Violations in Maintainer Acts include: a maintainer engages in practices, condoned by management, that bend the rules (Routine); a maintainer elects to stray from accepted procedures to save time, bending a rule (Infraction); a maintainer, due to perceived pressure, omits an inspection and signs off an aircraft (Exceptional); and a maintainer willfully breaks standing rules disregarding the consequences (Flagrant).

References

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